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(56) Documents Cited
GB 2312359 A EP 0805572 A2 EP 0648032 A1
EP 0643493 A1 WO 97/27686 A1 WO 97/14235 A1
US 5850405 A

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(54) Abstract Title

Detection of unreliable frames in digital data transmission systems

(57) An unreliable frame detection mechanism is implemented after the equalisation and de-interleaving stages of a GSM radio receiver (1). Two sequences of symbols (Z, T) are compared bit by bit and the number of differences computed (6). When any differences exist an unreliable frame is indicated (7) to the codec. The first of the two sequences (Z) is derived by forward convolutional decoding (2) of the received frame. The second of the two sequences (T) is derived by time reversal and coding of the received frame (3), convolutional decoding of the time reversed coded frame (4) and further time reversal of the time reversed decoded frame (5).

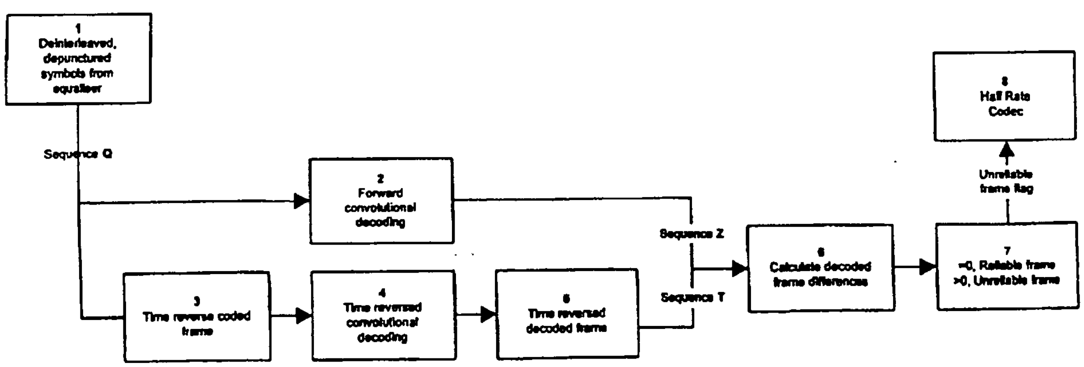

Figure 1

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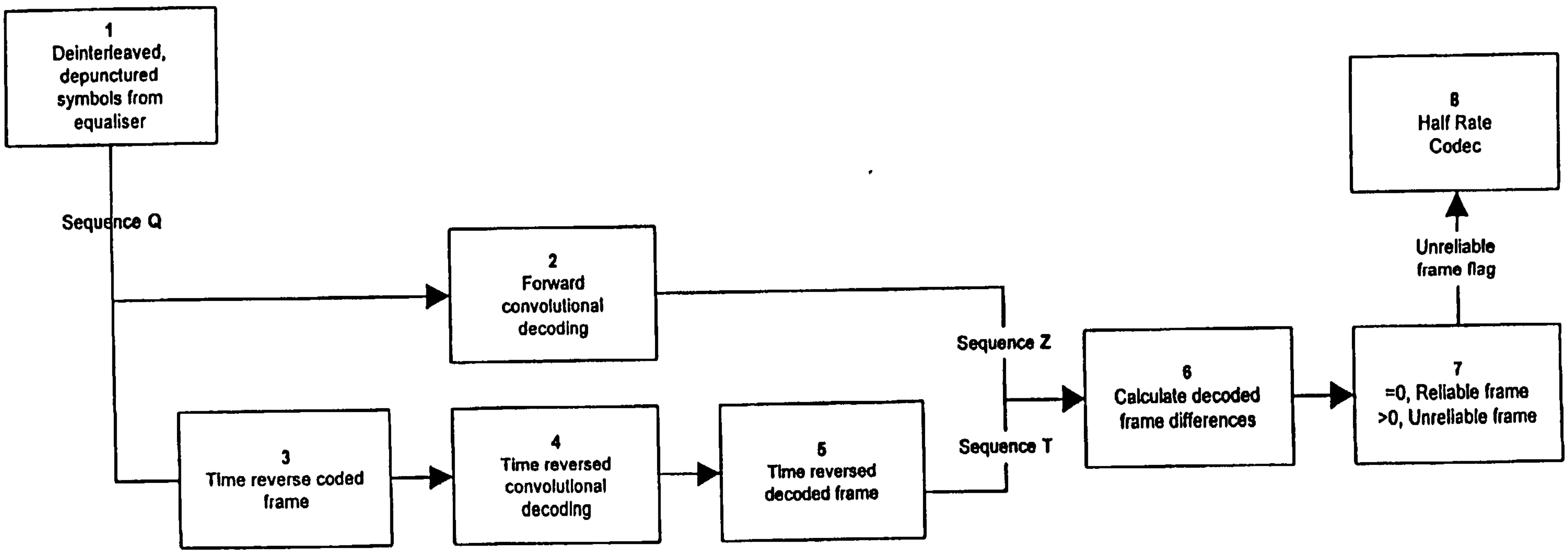

1
Deinterleaved,
depunctured
symbols from
equaliser
Sequence Q
2
Forward
convolutional
decoding
3
Time reverse coded
frame
4
Time reversed
convolutional
decoding
5
Time reversed
decoded frame
Sequence Z
Sequence T
6
Calculate decoded
frame differences
7
=0, Reliable frame
>0, Unreliable frame
Unreliable
frame flag
8
Half Rate
Codec

Figure 1

Detection of Unreliable Frames in Digital Data Transmission Systems

This invention relates to digital data transmission and in particular it relates to digital data decoders. The following description is based on the GSM cellular communications system for which the invention is of particular utility. It will be apparent to those skilled in the art, however that the invention may be applied to other systems of digital data transmission.

Reference is made to US patents 5 598 506 and 5 596 678 to Wigren et al US 5 557 639 to Heikkila and "Mobile Radio Communications" published by John Wiley & Sons, Raymond Steele (Ed.) for a description of the prior art and technological background. The following abbreviations are used herein:

GSM	- *Global System for Mobile communications,* (formerly *Groupe Special Mobile*)
TCH/FS	- *Traffic channel full rate*
TCH/HS	- *Traffic channel half rate*
CRC	- *Cyclic redundancy check*
PBER	- *Pseudo bit error rate*

The GSM cellular communications system may use the Half Rate speech codec. The Half Rate speech codec encodes sixteen, 8 kHz samples into 112 bits containing 18 parameters. These 112 bits are divided into two groups based on their subjective importance to speech quality. The 17 least important bits are known as class II bits and are unprotected.

Corruption of these class II bits has minimal audible effect on speech quality. The most important 95 bits are known as class I bits and are protected by additional convolutional coding. The class I bits are further subdivided into Ia and Ib, such that the most significant 22 bits (Ia) are additionally protected by a 3 bit cyclic redundancy check (CRC). All of the class I bits and class Ia CRC check bits are protected by a 1/3 rate convolutional code of constraint length **K**=7, which is punctured to reduce the number of transmitted encoded bits by one third before transmission.

In order to prevent any audio artefacts after speech transmission and decoding, any frame erasure and concealment mechanism must detect all frames with any class Ia errors and frames with more than a certain number of class Ib errors, as precisely and efficiently as possible for all propagation channel types. For the GSM Full Rate and GSM Enhanced Full Rate speech codecs this is achieved by marking such frames as bad to the speech codecs using an algorithm referred to as the frame erasure algorithm.

In this respect the Half Rate speech codec differs from the other GSM specified codecs because in addition to a mechanism for marking a received speech frame as bad, it requires an extra mechanism for marking a received frame as unreliable and utilises an algorithm known as the 'unreliable frame erasure algorithm'.

When a received speech frame is marked as bad the speech codec erases the frame and applies a concealment algorithm in order to mask the effects of the bad frame from the user. When a received speech frame is marked as

unreliable the speech codec performs its own validation check on the speech frame. If the validation check fails then the speech codec erases the failing speech frame. If the validation check passes then the speech frame is considered to be good and is used by the codec. This internal test performed by the speech codec is based on exploiting known properties of human speech, namely that the energy in speech varies slowly and thus it is unlikely that abrupt changes will be experienced.

The internal test is implemented by calculating the difference of an energy metric between the last good received speech frame and the current unreliable frame. If this energy difference is greater that some predetermined threshold then the frame is deemed bad and erased.

Thus it is apparent that two different algorithms are required by the Half Rate speech codec, one for detecting bad frames and the other for detecting unreliable frames. The conventional bad frame detection algorithm is composed of two parts:

a 3 bit CRC check

and a PBER threshold test.

The CRC check is made on the received speech frame by recalculating the CRC for the 22 class Ia bits and comparing this value to the received value. If they are different the CRC check is deemed to have failed. The PBER is calculated by re-encoding and puncturing the decoded received class I bits, comparing them bit by bit with the original received class I bits and counting the number of differences. If the specified PBER (P_{bad}) threshold has been

exceeded then the PBER threshold test is deemed to have failed. If either of these two tests fail then the received speech frame is marked as bad.

The conventional unreliable frame detection algorithm also makes use of a PBER threshold test for which the PBER is calculated in the manner described above, except that the threshold P_{unrel} is less than P_{bad}. Frames which have a calculated PBER higher than P_{bad} are marked as bad and frames with a PBER greater than P_{unrel} but lower that P_{bad} are marked as unreliable whilst frames with a PBER less than P_{unrel} are by definition good frames. A frame marked as bad is automatically considered unreliable whereas an unreliable frame is not necessarily bad.

The method of selecting unreliable frames described above does not work as efficiently as is possible because the method is based on the assumption that the calculated PBER is highly correlated with the true number of bits in error. This assumption does not hold when convolutional decoding breakdown begins to occur and unreliable frames are not marked as such.

An object of the present invention is to improve unreliable frame detection performance for speech channels such as the Half Rate GSM speech channel, to provide better audio performance.

According to the invention there is provided method for selecting unreliable frames in a digital data transmission system comprising after equalisation and de-interleaving selecting frames as either unreliable or bad in accordance with the result of a comparison of a sequence of convolutionally decoded symbols

with copy of the sequence of convolutionally decoded symbols, said copy having been symbol reversed, convolutionally decoded, and further bit reversed.

One example of the invention will now be described with reference to the sole figure 1, which illustrates an unreliable frame detection mechanism according to the invention. This algorithm is designed to detect breakdown in the convolutional decoding process and thereby to determine whether or not the data protected by the convolutional code may be considered reliable. This breakdown condition of convolutional decoding is characterised by a burst of essentially random errors being produced until the decoding process re-synchronises.

In this example a TCH/HS GSM channel is described, however, more generally is presented a method for identifying an unreliable frame in a digital data transmission system

After equalisation, de-interleaving, de-puncturing and convolutional decoding of the **n** encoded received bits (including 95 class I bits, 3 CRC bits, 6 tail bits), using a trace back length of **x** less than or equal to **n**, to produce a first sequence of **n** decoded bits; convolutionally decoding a copy of the **n** encoded received bits in a time reversed direction using a trace back length of y, where **y** is less than or equal to **n,** to produce **n** time reversed decoded bits; time reversing again the **n** time reversed bits, deleting the bit offset **R** (**R**=**k**-1, **k**=constraint length =7) caused by the reverse decoding process to produce a second sequence, comparing the first **n-R** bits of the first sequence with the

first **n-R** bits of the second sequence and selecting the received frame as either reliable or unreliable in accordance with the result of the comparison.

A frame is marked as unreliable when a number of differences greater than zero is computed in the comparison between the forward and backward decoded bits.

The instant unreliable frame detection mechanism is implemented after the usual equalisation and de-interleaving stages of a GSM radio receiver as follows. With reference to figure 1 which illustrates an unreliable frame detection mechanism, the sequences **Q, Z** and **T** are identified as such for clarity in the following description.

The output from **1** in figure 1 is the sequence of encoded symbols derived from a received frame after equalisation, de-interleaving and de-puncturing (sequence **Q**). Forward convolutional decoding at **2** of the received 211 coded symbols is effected using a trace back length of **x** symbols (**x** less than 105, typically 31), to produce 95 decoded class I bits, 6 tail bits and 3 CRC bits (sequence **Z**). A copy of the received 211 coded symbols (sequence **Q**) is time reversed at **3** and the time reversed sequence direction convolutionally decoded at **4**, using a trace back length of **y** symbols (**y** less than 105, typically 15), to produce 95 decoded class I bits, 6 tail bits and 3 CRC bits which are time reversed

The time reversed set of bits is again time reversed in **5**, thereby reverting to the original time ordering and becomes sequence **T**. The first 6 bits of

sequence **T** are deleted and sequence **T** is compared bit by bit with sequence **Z** for the first 99 bits and the number of differences between sequence T and sequence Z computed in **6**. Where differences are found between sequence **Z** and sequence **T**, the received frame is marked as unreliable (**7**). If no differences are found in the comparison of the two sequences T and Z then the frame is marked as reliable.

Time reversed decoding of any linear convolutional code, where the start and finish states are known, may be achieved by reversing the order of the generator polynomials and also reversing the order in which the bits contribute to the produced symbol. As an example consider the **n**=3, **K**=7 coding used by a GSM TCH/HS channel. The characteristic polynomials are defined as:

$G_0=1+D^2+D^3+D^5+D^6$ (1 0 1 1 0 1 1)

$G_1=1+D+D^4+D^6$ (1 1 0 0 1 0 1)

$G_2=1+D+D^2+D^3+D^4+D^6$ (1 1 1 1 1 0 1)

The time reversed version is then given by:

$T_0=1+D^2+D^3+D^4+D^5+D^6$ (1 0 1 1 1 1 1)

$T_1=1+D^2+D^5+D^6$ (1 0 1 0 0 1 1)

$T_2=1+D^1+D^3+D^4+D^6$ (1 1 0 1 1 0 1)

Using the modified coding scheme, decoding may then be performed in the time reversed direction, however, allowance must be made for a **K**-1 bit alignment error which is incurred from this time reversed decoding procedure.

Account must be taken of the 6 bit offset introduced into the time reversed bits due to the time reversed decoding procedure by deleting these first 6 bits output from **5**, the backward decode, thereby producing sequence **T**. The first 99 bits of sequence **Z** are compared to the first 99 bits of sequence **T** in **6** and the number of differences calculated. If no differences exist then the received frame is marked as reliable, otherwise the frame is marked as unreliable in **7** and passed to the Half rate speech codec in **8**.

Values of track back length **x** and **y** and may be chosen empirically such that the best performance of this algorithm is achieved for the desired channel propagation conditions.

CLAIMS

1. A method for selecting unreliable frames in a digital data transmission system comprising after equalisation and de-interleaving selecting frames as either reliable or unreliable in accordance with the result of a comparison of a sequence of convolutionally decoded symbols with copy of the sequence of convolutionally decoded symbols, said copy having been symbol reversed, convolutionally decoded, and further bit reversed.

2. A method for selecting unreliable frames in a digital data transmission system as in claim 1 in which the result of the comparison of said sequence of convolutionally decoded symbols with said copy of the sequence of convolutionally decoded symbols is a computation of a number of differences.

3. A method for identifying unreliable frames in a digital TCH/HS GSM channel comprising after equalisation, de-interleaving and de-puncturing, convolutional decoding of the **n** encoded received bits to provide a first sequence, convolutional decoding a copy of the **n** encoded received bits in a time reversed direction, to produce **n** time reversed decoded bits, time reversing again the **n** time reversed bits and deleting the bit offset **R** caused by the reverse decoding process to provide a second sequence, comparing the first **n-R** bits of the first sequence with the first **n-R** bits of the second sequence and selecting the received frame as either reliable or unreliable in accordance with the result of the comparison.

4. A method for selecting unreliable frames in a digital data transmission system as in claim 3 in which the result of the comparison of said first sequence with said second sequence a computation of a number of differences.

5. A method for selecting unreliable frames in a digital data transmission system as in claims 2 or 4 in which an unreliable frame is selected as reliable when the number of differences computed is zero.

The Patent Office

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Claims searched:	1-5	**Date of search:**	3 September 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4P (PEL, PEM, PEP, PEV)

Int Cl (Ed.6): H04L 1/00, 1/20; H03M 13/00, 13/12, 13/22

Other: Online EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2312359 A	Motorola Inc. - see abstract; page 17, lines 16-29	1,3
A	EP 0805572 A2	Texas Instruments Inc. - see abstract	1,3
A	EP 0648032 A1	Nokia Mobile Phones - see abstract (& US 5557639)	1,3
A	EP 0643493 A1	Hughes Aircraft Co. - see abstract	1,3
A	WO 97/27686 A1	Nokia Telecom. - see abstract	1,3
A	WO 97/14235 A1	British Telecom.- see abstract	1,3
A	US 5850405	Siemens AG - see column 1, line 61 to column 2, line 51	1,3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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